Socio-economic Scenarios in the Climate Changes Spatial Planning and the Knowledge for Climate Programmes

van Drunen, M.A.; Berkhout, F.G.H.

2009

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Michiel van Drunen

Frans Berkhout

Report W-09/16
December 2009

This report was commissioned by: Climate *changes* Spatial Planning
It was internally reviewed by: -

IVM
Institute for Environmental Studies
Vrije Universiteit
De Boelelaan 1087
1081 HV Amsterdam
The Netherlands
Tel. +31-20-5989 555
Fax. +31-20-5989 553
E-mail: info@ivm.falw.vu.nl

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1 Introduction

The Climate *changes* Spatial Planning (CcSP) programme aims 'to introduce climate change and climate variability as one of the guiding principles for spatial planning in the Netherlands' (CcSP, 2009). However for planning purposes not only a changing climate must be taken into account, but also a changing society. Both future climate *and* future society scenarios need to be compared to the current climate and current society to assess the impacts of climate change. Moreover, there are likely to be all kinds of interactions between the future climate and the future society. For example, in a warmer climate people may spend more time outdoors and therefore the demand for recreation space would be expected to increase. The Intergovernmental Panel on Climate Change showed that the socio-economic characteristics of future societies determine their greenhouse gas emissions and therefore have significant impacts on our future climate (IPCC, 2000).

The CcSP programme initiated the project Socio-economic Scenarios for Climate Assessments (IC11) to review existing socio-economic scenarios for the Netherlands and internationally, and to make scenario data accessible for researchers in the CcSP programme and other stakeholders. So far, the project resulted in a literature review (Berkhout and Van Drunen, 2007), a workshop report (Van Drunen et al., 2007), an assessment of user needs (Eeltink and Van Drunen, 2008), a report on the use of socio-economic scenarios in climate assessments (Van Drunen and Berkhout, 2008), a guidance document (Van Drunen and Berkhout, 2009) and an interactive website (Climatescenarios.nl, 2009). IC11 is one of the CcSP integration projects. These projects aim at making knowledge available and applicable for stakeholders.

This report draws the main conclusions from earlier work in IC11 to inform and advise the CcSP board about the application of socio-economic scenarios in climate assessments. In addition it formulates issues for further research, which are intended for the CcSP programme successor Knowledge for Climate (KfC). It addresses the following questions:

1. What scenario studies are relevant for climate assessments in the Netherlands?
2. How can these scenarios be adapted to be useful in CcSP and Knowledge for Climate (KfC) projects?
3. Do all scenarios of a particular scenario study need to be taken into account?
4. Are there preferred combinations of socio-economic and climate scenarios? I.e. is it reasonable to combine low emission socio-economic scenarios with climate change scenarios with small temperature increases and high emission scenarios with climate scenarios with high temperature increases or do all combinations need to be considered?
5. What are examples of good practice?
6. Where can climate researchers obtain socio-economic scenario data?
7. What further research is required?

These questions will be addressed in the following chapters. Chapter 2 provides a brief introduction on the use of scenarios in climate assessments. Chapter 3 discusses the Future of the Dutch Built Environment (WLO) scenarios and outlines how these scenarios can be applied in practice. Climate scenarios and socio-economic scenarios tend to be developed separately. Therefore they need to be combined for practical purposes. Chapter 4 gives some suggestions how to do this. The IC11 project introduced an interactive website that provides values for societal and economic parameters in socio-economic scenarios. How these numbers can be used whilst assessing adaptation and mitigation options is explained in Chapter 5. In Chapter 6, we discuss two CcSP projects extensively applied the scenario method. We conclude this report with a chapter about future research and recommendations for the Knowledge for Climate programme.

2 Socio-economic scenario studies

Socio-economic scenario exercises may be defined as being exploratory, extrapolatory or normative in approach. Extrapolatory scenario studies make extrapolations of current trends. They provide valuable information on the short term (e.g. in the coming five years). Normative scenario studies picture a desirable society in the future, e.g. a carbon free electricity production system or the Netherlands protected to 130 cm sea level rise in 2100. They derive sets of policy measures that need to be taken in time to meet this desirable society. This often referred to as *backcasting*, i.e. the future is taken as a reference point, whereas in forecasting (extrapolatory) the current society is taken as a reference point. In a backcasting exercise a stepwise approach is designed to meet the predefined target (Berkhout and Van Drunen, 2007).

Exploratory approaches create a stylised 'model' of a system and make projections for the system given assumptions about the determinants of change. The objective of exploratory scenario studies is to explore the 'uncertainty space': they address the questions what the most relevant uncertainties are and how they may influence future society. Since most scenario studies take an exploratory approach (Berkhout and Van Drunen, 2007) and because exploratory scenarios are most relevant for climate assessments we elaborate these further.

Global scenarios are exercises that provide an integrated picture of future developments and they are frequently used to frame global assessments of environmental problems. By implication, they are concerned with characterizing multiple driving forces and contexts for change in the future. The main results include both specific projections (GHG emissions rates) and statements about the general state or capacity of global economic or ecological systems. Many global scenarios share common intellectual roots, share convergent visions of the future and have applied the *scenario-axis technique* (Van 't Klooster and Van Asselt, 2006). This technique is currently the dominant paradigm in scenario studies (Van 't Klooster, personal communication).

The scenario-axis technique comprises the identification of two key uncertainties that determine a graph with the subsequent axes. In each quartile of the co-ordinate system generated by the key uncertainties narratives are drawn up: stories about the societies that would develop given the conditions set (Figure 1 on page 4 provides an example). The choice of choosing *two* key uncertainties is somewhat arbitrary and has a pragmatic basis. The number of generated scenarios (four) presents a compromise (Berkhout and Hertin, 2002):

1. Two are too narrow to depict the full 'uncertainty space';
2. Three lead to a best guess (the middle one), which is undesirable because it is not known what scenario is most probable; and
3. More than four is too difficult to manage for most stakeholders.

E.g. Shell (2007) introduced a method based on *three* key uncertainties, which they reframed into objectives: efficiency, social cohesion and security. Shell argues that it is impossible to meet all three objectives in a future world, because meeting one objective would lead to trade-offs regarding the other two. Hence, instead of exploring all nine possible combinations, they decided to focus on only three. In these three scenarios, two objectives 'win' and one 'looses'.

The IPCC applied the scenario axis technique for its SRES greenhouse gas emission scenarios (IPCC, 2000), and it was applied in Futures Foresight (Berkhout and Hertin, 2002) and in the Millenium Ecosystem Assessment (2005). In these studies approximately the same key uncertainties were assumed. The main advantages of the scenario axis method are (Berkhout and Hertin, 2002):

- A degree of analytical rigour;
- It provides a frame for participative scenario exercises for broad groups of participants;

The Dutch study The Future of the Dutch Natural and Built Environment (Welvaart en Leefomgeving - WLO) shares many similarities with the scenario studies mentioned above. It applied the scenario axis method that was based on comparable key uncertainties. WLO formulated them as follows (WLO, 2006: 45): (1) To which extent will nations and international trade blocks cooperate and exchange, giving up some of their cultural identity and sovereignty? (2) How will governments balance between market forces and a strong public sector?' Hence in WLO the key uncertainties are globalization and liberalization. Table 1 shows that e.g. the WLO 'Global economy' scenario has similarities with the IPCC/SRES A1 scenario, the WBCSD 'FROG!' scenario, the GEO-3 'Markets first scenario', the WWV 'B-a-u' scenario and the Futures Foresight 'World Markets scenario'.

Table 1 Similarities between the socio-economic scenarios SRES (IPCC, 2000), WBCSD (1997), GEO-3 (UNEP 2002), WWV (2000), OECD (2001), Foresight Futures (2002) and WLO (2006). Source: Adapted from the Millenium Ecosystem Assessment (2005).

Scenario	SRES	WBCSD	GEO-3	WWV	OECD	Foresight Futures	WLO
Conventional worlds							
Market forces	A1	FROG!	Markets first	B-a-u	Refe-rence	World Markets	Global Economy
Policy reform	B1	GEO-Polity	Policy first	Technology and economics	Policy variants	Global Sustain-ability	Strong Europe
Barbarization							
Breakdown	A2					National Enterprise	Transatlantic Markets
Fortress world			Security first				
Great transitions							
Eco-communalism	B2					Local Steward-ship	Regional Communities
New sustainability paradigm		Jazz	Sustaina-bility first	Lifestyle and values			

Based on a workshop with CcSP researchers (Van Drunen et al., 2007) and a user needs survey (Eeltink and Van Drunen, 2008), we conclude that WLO is a useful basis for socio-economic scenarios in the CcSP programme. WLO, as a highly quantitative scenario study, generated figures and data that are useful for climate assessments (Van Drunen en Berkhout, 2008). Furthermore, WLO scenarios have already been applied in studies where climate change is an important factor, such as the *Optiedocument energie* and *Nederland Later*.

In the next chapter we summarize the key features of the WLO scenarios. In addition we evaluate some of its features based on literature data.

3 Building on existing scenarios

3.1 The Future of the Dutch Natural and Built Environment (WLO)

The Future of the Dutch Natural and Built Environment (WLO) is the most recent and elaborate socio-economic scenario study in the Netherlands. It assesses the long-term effects of current government policy, given the international economic and demographic context of the Netherlands (WLO, 2006). By exploring how land use and various aspects of the living environment may develop on the long run (2040), the study shows when current policy objectives may come under pressure, and which new issues may emerge. The study builds on earlier work by CPB in which the scenarios were translated into development paths for the Dutch economy and demography. In WLO, these scenarios were elaborated for application to the built and natural environment. The four WLO scenarios are shown in Figure 1.

Figure 1 The four WLO scenarios.

The key trends assessed in WLO are economic growth, labour productivity, population growth, institutional development, international co-operation, energy use, mobility and congestion, and land use. WLO assumes that the socio-economic developments are not different for the four KNMI (Royal Netherlands Meteorological Institute) climate scenarios. The justification of this assumption is discussed in sections 4.2 and **Error! Reference source not found.**.

Although the scenario axis method applied in WLO is an exploratory approach, WLO has also extrapolatory characteristics. The WLO research team initially divided the time frame into the period until 2020 and the period 2020-2040. They argued that the first period could be explored by trend extrapolations based on historical data sets. The second time period was considered as ‘the far future’. The researchers acknowledged that it in this time period existing structures and mechanisms will be changing or replaced by others. Therefore they wanted to explore a range of possible futures and uncertainties. However in the process of refining the scenarios, future images that are quite different from our existing world were considered unrealistic and therefore dropped in the analysis. This was observed by Van ’t Klooster (2007: 140) who concluded that in WLO the historic-deterministic pattern of reasoning dominated not only in the time period until 2020, but throughout the whole period that was investigated. Hence, it did not fully succeed in exploring the complete ‘uncertainty space’ set-up by the key uncertainties.

For climate assessments it is important to extend the time horizon to 2100 or even further (Van Drunen et al., 2007). One of the few scenario studies that look into the second half of this century is the SRES study (IPCC, 2000). The SRES scenarios focus on greenhouse gas emissions and therefore specifically provide data about driving forces such as demographic development, socio-economic development, and technological change. Like the WLO study, SRES does not take into account new (climate) policies.

TNO (Jonkhoff et al., 2008) also made an attempt to set up socio-economic scenarios for 2100. They extended the WLO scenarios for The Netherlands until 2100 by extrapolation. In addition they made combinations with climate scenarios. As already noted in Chapter 2, the SRES and many other commonly applied long-term scenarios are quite similar to the WLO scenarios.

As a formal scenario exercise WLO coupled approximately forty quantitative models. These models include a global model that assesses economic developments, trade and energy supply, national and regional demographic models, a labour market model, transport models for persons and freight, an agricultural model, energy models and environmental models (WLO, 2006: 205-209). The models are hosted by many different governmental and non-governmental organizations, such as CPB, MNP, RPB, CBS, RIVM, ECN, LEI, ABF Research and Louter Advies. Dekkers and Koomen (2006) concluded that some of the underlying WLO models are well validated and calibrated, but that at least one is not well documented at all. This complicates the assessment of the validity of the WLO outcomes. In the model calculations no feedbacks were included, such as the effects of congestion on economic growth. Such feedbacks may be relevant in climate assessments.

Since WLO is not a single model, but a combination of many individual models that were developed by several institutes and run on several different computers on different locations it is complicated to re-run the scenarios with different input parameters. This complicates its practical use in climate assessments.

3.2 Choosing scenarios

Although WLO has several methodological and practical shortcomings, as indicated in Section 3.1, Van Drunen & Berkhout (2007) showed that WLO generated figures and data useful for climate assessment studies. Ideally the full range of uncertainties – i.e. all four storylines – are taken into account in studies that assess socio-economic developments. However in practice, mostly only one or two scenarios are chosen, because of resource constraints and perceived salience of scenarios. In some studies, scenarios are ignored because they are considered unlikely or irrelevant. From a theoretical point of view this selective ‘shopping’ may lead to a tunnel vision, because it is impossible to estimate which scenario is more probable than others. Therefore we recommend taking all four scenarios into account, especially in the first phase of the process (see also Foresight Futures, 2002).

In case of resource constraints, the most elegant approach is to estimate which scenario would lead to a worst case or which scenarios would lead to the least and most severe impacts. E.g. the LANDS project (Climate Change Spatial Planning: IC3) included the Global Economy (GE) scenario and the Regional Communities (RC) scenario to assess the possible futures (see Section 6.3).

Foresight Futures (2002) recommends combining scenarios in certain occasions when it is impossible to take all scenarios into account. In the Climate changes Spatial Planning and Knowledge for Climate programmes this is not recommended, because such combinations would make it more difficult to compare the results of the individual projects.

3.3 Tailoring existing scenarios

Scenarios are used in a broad range of studies. Since scenarios do not result in future *projections* but rather depict ‘uncertainty ranges’, each problem has its own specificities regarding scenario outputs. Therefore, existing scenario studies – such as WLO – cannot be directly applied. Instead, they must be tailored with specific information relevant to the problem. The integration between the ready-made scenarios and the problem-specific information cannot be done by scenarios experts alone; instead stakeholder participation is fundamental. A common way to do this is as follows.

To stimulate thought, usually small scale events are organized. They start with a presentation of the scenarios, followed by a brainstorming session to consider the implications. Involving representatives from all interested parties is essential. The events are participative and serve as a mechanism to engage key people in the development of strategies (Foresight Futures, 2002).

To use scenarios on a specific sector or issue (e.g. the energy sector, or water security) data are required in addition to expert knowledge. Hence, scientific methods – usually models – need to be applied (Foresight Futures, 2002). The WLO study already did this for some sectors, such as agriculture and housing. The most difficult part here is to combine the qualitative, general storylines with quantitative models.

WLO presents its spatially relevant data mostly on a regional level. The three regions defined are the *Randstad* (Noord-Holland, Zuid-Holland and Utrecht), the *Transition Zone* (Flevoland, Gelderland and Noord-Brabant), and *Other* provinces. Data on provincial level and COROP level (forty regions distinguished in Dutch statistical records) are available from the WLO developers. For the theme water security, dike rings were chosen as spatial unit. The LANDS project (Riedijk et al., 2007) presented land use maps on a 100 meter grid based on the models and data provided by WLO (see also Section 6.3).

An overview of the most important available data in Europe, The Netherlands, The Randstad, The Transition Zone and the other provinces in 2002, 2020, 2040, 2070 and 2100 is available from www.climatescenarios.nl (see Chapter 5). To tailor existing scenarios the practical steps to be taken include (Foresight Futures, 2002):

- **Engage stakeholders.** (a) Be open about the aim and the limitations of the scenario exercise. (b) Provide enough details about the scenarios to enable the stakeholders familiarizing with them. E.g. they can be asked in a workshop setting to connect future newspaper headlines to the different scenarios. (c) Explain what will be done with results.
- **Get the process right.** A typical structure for the workshop might be: aim of the process, introduction scenario approach, presentation of scenarios, elaboration of scenarios in break-out groups, feedback, planning next steps. Generally the workshop is moderated by a professional with scenario experience. It is important to devote equivalent efforts to all scenarios and to ensure that the subsequent scenarios remain distinct and coherent. Hence in several steps in the process they need to be carefully compared. E.g. the Safety First project (Section 6.2) organized a workshop at the start of the project with WLO developers, and stakeholders from research institutes, the Directorate-General for Public Works and Water Management, etc. The workshop included presentations and an exercise to experience the different WLO scenarios. Finally, the participants assessed the usefulness of WLO for water safety issues. The workshop was moderated by scenario experts from Pantopicon.
- **Adapting scenarios.** In general, scenarios need to be adapted for specific cases. E.g. in certain sectors the key drivers may be different than the ones chosen in WLO. It is also possible to introduce an additional driver. E.g. in SRES (IPCC, 2000) technological development was added to the A1 scenarios as a third driver. In the CcSP programme we recommend to connect as closely to the WLO scenarios as possible to enable comparing the different project results. In many projects policy recommendations will be generated. The robustness of these policies in the different scenarios can be tested similarly as in Nederland Later (MNP, 2007: 54). We recommend participants to think about possible feedback mechanisms, especially because they are mostly ignored in WLO. This allows learning processes to be taken into account. One option would be to organize this round of the evaluation as a 'game-playing' simulation.
- **Take account of discontinuities.** The resilience of scenarios can be tested to apply discontinuities and assessing how easily they recover from or adapt to the impacts. In case of slow changes in the direction of change one can shift from one scenario to another. See also Section 7.4. Safety First organized a workshop completely

devoted to discontinuities. First it was explained to the participants what discontinuities are. Then, the participants were challenged to formulate discontinuities relevant for water safety in the Netherlands. The workshop included an ‘inspiration injection’ and a plenary feedback on the formulated discontinuities.
- **Integrate ‘future thinking’.** Integration of scenario planning in organizations would make them more aware of early warning signs for trends and would develop ways of increasing their adaptive capacity. Many organizations would benefit from imbedding scenario routines in their decision making processes.

In climate assessments socio-economic scenarios are relevant, but usually the focus is on climate scenarios. The next chapter introduces the climate scenarios developed by the Royal Netherlands Meteorological Institute and it reflects on combining these scenarios with the WLO socio-economic scenarios discussed in this chapter.

4 Combining socio-economic scenarios with climate scenarios

4.1 Climate scenarios

The Royal Netherlands Meteorological Institute (KNMI) developed four climate scenarios for The Netherlands in 2006. The G scenario is a moderate scenario that involves an average global temperature increase of 1ºC in 2050 compared to 1990. In this scenario, the air circulation patterns remain unchanged. In the W scenario the global temperature will increase by 2ºC in 2050. The G+ and W+ involve temperature increases of 1 and 2ºC *and* changes in the air circulation patterns. Specifically, in the '+' scenarios there will be more easterly winds in the summer and more westerly winds in the winter causing warmer and dryer summers and milder and wetter winters. The anticipated temperature increase depends on greenhouse gas emissions (and thus on socio-economic scenarios) whilst the anticipated change in circulation patterns (or not) depend on physical uncertainties. The key features of the four scenarios are summarized in Table 2 (KNMI, 2006).

Table 2 The KNMI 2006 climate scenarios (KNMI, 2006).

		G	G+	W	W+
Global temperature rise		1ºC	1ºC	2ºC	2ºC
Change in air circulation patterns		No	Yes	No	Yes
Winter	Average temperature	+0.9 ºC	+1.1 ºC	+1.8 ºC	+2.3 ºC
	Average precipitation	+4%	+7%	+7%	+14%
Summer	Average temperature	+0.9 ºC	+1.4 ºC	+1.7 ºC	+2.8 ºC
	Average precipitation	+3%	-10%	+6%	-19%
Sea level	Absolute increase	15-25 cm	15-25 cm	20-35 cm	20-35 cm

Table 2 shows that for 2050 the differences between the four scenarios are quite substantial. E.g. average winter temperature is 0.9ºC higher in the moderate G scenario and 2.3ºC higher in the warm W+ scenario, compared to the average situation in the period 1974-2005. WLO did not use the KNMI 2006 scenarios but the central scenario published in 2000 that indicated an average temperature increase of 1ºC in 2050. This central scenario can be compared to the KNMI 2006 G scenario (Riedijk et al., 2007).

4.2 The relationships between climate and society

4.2.1 Human impacts on the global climate

The SRES scenarios (IPCC, 2000) assess greenhouse gas emissions in four socio-economic scenario types. The IPCC Fourth Assessment Report (Meehl et al., 2007) applies these emissions scenarios to estimate the impacts on climate change. It concludes that (p. 749):

> *"There is close agreement of globally averaged mean warming for the early 21st century for concentrations derived from the three non-mitigated [...] SRES*

> *scenarios. By mid-century (2046–2065), the choice of scenario becomes more important for the magnitude of […] warming, with values of +1.3°C, +1.8°C and +1.7°C for B1, A1B and A2, respectively. About a third of that warming is projected to be due to climate change that is already committed. By late century (2090–2099), differences between scenarios are large […].The warming and associated uncertainty ranges for 2090 to 2099 relative to 1980 to 1999 are B1:* ***+1.8°C*** *(1.1°C to 2.9°C), A1B:* ***+2.8°C*** *(1.7°C to 4.4°C), and A2* ***+3.4°C*** *(2.0°C to 5.4°C)."*

Hence, since the global warming in the first half of this century is largely determined by historic greenhouse gas emissions, the estimated temperature rise around 2050 are fairly independent of the socio-economic emission scenarios. This is different from the second half of the century. Here the temperature rise is heavily influenced by the emission scenarios: +1.8°C in a low emission scenario and +3.5°C in a high emission scenario. The brackets in the citation above indicate the range of outcomes of different climate models assessed by the IPCC.

4.2.2 Climate impacts on society

IPCC's Fourth Assessment Report estimates the effects of climate scenarios on the vulnerability of society (Schneider et al, 2007). It indicates that the impacts in several sectors are much higher if the global mean temperature increase is 4°C compared to 1°C. On p. 781 the IPCC concludes:

> *"Global mean temperature changes of up to 2°C above 1990-2000 levels would exacerbate current key impacts, and trigger others, such as reduced food security in many low-latitude nations (medium confidence). At the same time, some systems, such as global agricultural productivity, could benefit (low/medium confidence). Global mean temperature changes of 2 to 4°C above 1990-2000 levels would result in an increasing number of key impacts at all scales (high confidence), such as widespread loss of biodiversity, decreasing global agricultural productivity and commitment to widespread deglaciation of Greenland (high confidence) and West Antarctic (medium confidence) ice sheets."*

It can be concluded from Schneider et al. (2007) that the impacts of the different greenhouse gas emission scenarios are not large enough for vulnerability assessments to distinguish them until mid-century. The absolute and relative differences by 2100 are larger and the differences in impacts are also more evident.

Note that the climate scenarios for the Netherlands are more extreme, because of its geophysical characteristics. Already in 2050 the scenarios show markedly different results as shown in Table 2. For 2100 the average winter temperature is estimated to increase between 1.8°C and 4.6°C and the average summer temperature between 1.7°C and 5.6°C, relative to 1990 (KNMI, 2006). Because of the absence of mountainous areas and regular ice cover, and its adaptive capacity, the vulnerability of the Netherlands is considered relatively low. Most severe impacts are associated with flooding, droughts and periods with extreme rainfall (Kwadijk et al, 2006).

4.3 Combining socio-economic and climate scenarios

Since WLO and KNMI each outline four distinct scenarios, in principle sixteen combinations are possible. Working with sixteen combined scenarios is in many cases not feasible because of budget and time constraints. In addition, it is for stakeholders usually impossible to deal with such a high number of scenarios. Fortunately, the number of combinations can be cut down because of a number of reasons. They are elaborated below.

Based on the IPCC conclusions cited above it can be concluded that probably socio-economic development is not much affected by climate change until mid-century. Also, climate until mid-century is to a large extent determined by past greenhouse gas emissions and is therefore not much affected by socio-economic developments. Both interpretations are not valid anymore in the second half of the century. Then, the climate scenarios with the high temperatures are associated with the socio-economic scenarios that result in high GHG emissions. This suggests that in this period socio-economic scenarios must consider the impacts of climate change as one of the drivers for change. The CcSP study LANDS and the TNO study did this in similar ways. They are briefly discussed below.

LANDS (Riedijk et al., 2007) associated the Global Economy scenario with the warm (W) KNMI 2006 scenarios and the Regional Communities scenario with the moderate (G) scenarios. The LANDS team argues that the RC scenario would lead to the lowest greenhouse gas emissions resulting in a lowest average temperature increase. The opposite would be true for GE. Hence, LANDS ignored the Transatlantic Market and Strong Europe scenarios which would generate greenhouse gas emissions in between. More background information about LANDS is provided in Section 6.3. Since emissions have no influence on the wind patterns LANDS included the climate scenarios with and without changing wind patterns (see Table 3).

In case it is necessary to limit the number of scenarios to be assessed in future KfC projects we recommend to follow the same procedure as the LANDS project. Although some scenario users consider RC unlikely, it is important to take this scenario into account, to consider the full uncertainty range.

Table 3 Integrated scenarios in LANDS (Source: Riedijk et al., 2007: 23).

	Regional Communities	Global Economy
Circulation change	Moderate rise in Temperature (G+)	Strong increase in Temperature (W+)
No circulation change	Moderate rise in Temperature (G)	Strong increase in Temperature (W)

Jonkhoff et al. (2008) associated Global Economy with the G+ scenario, Transatlantic Market with the W scenario and Regional Communities with the G scenario. Table 4 shows three of the storylines developed by TNO. The other two consider the 'E'-scenarios, climate scenarios with a 3ºC global temperature increase, which are not considered here. These E scenarios are associated with Regional Communities and Global Economy.

Table 4 Storylines in the TNO study (Jonkhoff et al., 2008).

Name	SE-scenario	Climate scenario	Characteristics
Innovation	Global Economy	G+	Strong EU, global trade, high growth, limited environmental policies, global warming limited because of feedbacks
Middle	Transatlantic Market	W	EU politically weak, no global trade agreement, high growth, limited environmental policies, significant climate change
Conservatism	Regional Communities	G	National states remain important, trade blocks, slow growth, strict environmental policies, limited climate change

Table 4 shows that TNO, in contrast to LANDS, associated a G scenario with Global Economy. It also considered the Transatlantic Market scenario whilst LANDS did not. Similar to LANDS, TNO associated Regional Communities with G and ignored the

Strong Europe scenario. The combination of climate scenarios and socio-economic scenarios in the TNO study seems somewhat arbitrary. E.g. it can be argued that moderate climate change can be associated with low economic growth scenarios (RC and G), but it is not clear why the high growth Global Economy scenario is associated with the G+ scenario. Firstly, one would expect it to be associated with a W scenario (like in LANDS). Secondly, there is no relationship between possible changes in wind circulation patterns and greenhouse gas emissions.

The TNO study defined a ‘middle’ or trend scenario that was placed centrally with four alternative scenarios. The risk of such a trend scenario is that users will consider this the most probable scenario. Therefore the full range of uncertainties would not be explored.

This chapter provided an overview of the KNMI climate scenarios and how they relate to socio-economic scenarios. In IC11 we explored the WLO scenarios, combined them with KNMI scenarios and extended their time horizon. This resulted in sets of tables with key values relevant for climate assessments, which are presented in the next chapter.

5 Key numbers

5.1 Overview of scenario features

The framework explained in Chapter 3 calls for background parameters. With such parameters, researchers can start building their own scenarios. Ideally models would exist that enable scenarios developers to feed these models with there own inputs. For example, such models would generate scenarios for specific areas, years or sectors. Unfortunately reality is not that simple (see Section 3.1).

Therefore, the IC11 team decided to present overviews of key values for different regions (EU15, The Netherlands, Randstad, Transition area and Rural area) and different years (2020, 2040, 2070, 2100). The values relate to four themes: demography, economy, innovation and spatial developments. The indicators were selected during a workshop with three WLO developers and researchers from IVM and Deltares. The selection was primarily based on the inventory of user needs (Eeltink and Van Drunen, 2008) and expert judgement. Table 5 provides an example of the chosen indicators. Scenario developers can use these values as a starting point for *downscaling* or *tailoring* scenarios according to there needs in workshop settings as described in Section 3.3. In addition the numbers can be used for consistency checks. For example, Table 5 shows that in the Regional Communities scenario the GDP per capita is 23% lower than in Global Economy in 2020. This has many implications for, for example, financing public works for flood protection. Furthermore there are 1.5 million fewer people in Regional Communities than in Global Economy, which has significant implications for the number of new houses that would need to be built.

Table 5 Key numbers for The Netherlands in 2020. Climate would not affect these values in 2020. Source: Climatescenarios.nl (2009).

Theme	Indicator	Unit	Global Economy	Strong Europe	Trans-atlantic Markets	Regional Commu-nities
Demography	Population	Mln	18.0	17.7	17.0	16.5
	Labor participation	%	49	46	48	45
	Annual migration	1000	54	38	22	8
Economy	GDP per capita	k€	41.4	35.3	38.4	31.9
	Agr./Ind./CommServ./ NonCommServ.	%	2.1/21.2/ 55/22	2.0/21.2/ 56/21	2.0/20.9/ 57/20	2.3/20.2/ 54/23
	Income equality	--/0/++	--	0	-	+
Innovation	Labor product.	%/year	2.1	1.5	1.9	1.2
	Water security	M€/year	82	68	72	57
	Agriculture - labor prod.	%/year	3.8	2.7	3.0	2.6
	Energy consumption	PJ	4006	3555	3792	3215
	Energy- fossil	%	91	91	91	91
Spatial	Living	1000 ha	276	259	258	241
developments	Working	1000 ha	117	103	110	93
	Agriculture - animal husb.	1000 ha	1515	1488	1300	1457
	Agriculture - other	1000 ha	655	712	787	795
	Recreation	1000 ha	95	88	83	79
	Mobility	km/pp/yr	13944	13616	13823	13454
	Congestion	2002=100	127	87	81	64
	Nature	1000 ha	628	653	611	636
	Water storage increase	ha	1758	1230	1186	581

	2002					

5.2 Communicating climate risks and assessing adaptation options

Once socio-economic and (combinations with) climate scenarios have been established, all kinds of plans with implications for the far future, including options for adapting to climate change, can be assessed. This is a *problem-oriented approach* that focuses on the question: is the investigated plan future-proof? Alternatively, scenario results can be used to develop policies and measures. The Deltacommissie (2008) followed this *systems approach* for future flood protection. The key question is: how to design a future-proof society? Here future-proof can be framed in terms of *resistance* and *resilience.*

Systems (e.g. hydrological systems, urban systems) can be future-proof in many different ways. For example the Dutch flood protection system (dunes, dikes) has a very high *resistance* to sea level rise. The system is not likely to fail, but if it fails the impacts are very high and it will take much effort and time to restore the system. This is comparable to the marble in the square tube on the left side of Figure 2: it is hardly possible to move it by gently turning the tube, but once the marble is moved, it does not return to its original position. Other systems, such as the electricity production system are *resilient* to climate change impacts. In case of heat waves the cooling system of power plants at rivers can fail because the cooling water temperature increases too much. However the system will operate again very quickly when the temperature drops. This is comparable to the marble in the elliptic tube on the right side of Figure 2 (Kwadijk et al., 2006).

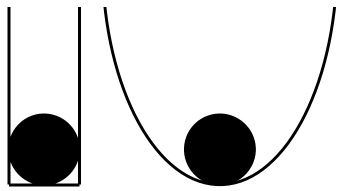

Figure 2 Schematic presentation of a system with a high resistance (left) and a system with a high resilience. Source: Kwadijk et al., 2006.

The systems approach aims at preparing for future needs. It tries to identify what may go wrong in the future if no appropriate action is taken. The approach also assesses what new policies may be needed in the future and therefore the scenarios in a systems approach typically do not include such new policies. E.g. the SRES (IPCC, 2000) and the WLO (2006) are scenario studies that apply this principle.

The Deltacommissie (2008) found a way out of the need to assess all kinds of possible futures by adopting a worst case scenario approach: it argued that flood protection is so important for the Netherlands that it should resist a sea level rise of 130 cm in 2100. If the recommended measures will be implemented society would be future-proof because the measures have been designed for the worst case. Of course the big disadvantage of this worst case scenario approach is that more resources than strictly necessary are likely to be spent: sea level rise may well be limited to lower levels than 130 cm.

The systems approach shares some similarities with *backcasting* approaches that were briefly introduced in Chapter 2. These are normative approaches where policies are being designed to reach some desired future. In fact backcasting was an important approach in one of the underlying projects for the Deltacommissie (Aerts et al., 2008).

Problem-oriented approaches do not start with scenario results but with policy plans. Key question is: what are the implications of the plan in case of different possible futures? For example in many CcSP projects adaptation options will be designed, i.e. measures that repair or prevent negative impacts of climate change. In these projects, the options have been formulated on the basis of the KNMI scenarios, which is a systems approach. However they should also be assessed against different socio-economic scenarios by applying a problem-oriented approach. For example the project *Waarheen met het Veen*? (ME1) argued that 'the water management [in the Zegveld peatland] should be adapted and should focus on methods to keep the water level in summer as high as possible. To minimize the subsidence, requires maintaining shallow groundwater levels. The agriculture will face wetter conditions.' (Querner et al., 2008: 623). However to assess the impacts of this adaptation measure on e.g. the agricultural sector, the socio-economic scenarios should also be taken into account. For example in the four WLO scenarios the area for animal husbandry in the Randstad varies between 170,000 (Transatlantic Markets-TM) and 203,000 ha (Regional Communities-RC) in 2040. Hence in TM the wetter conditions may be not very problematic, because the Zegveld peatland is not required for animal husbandry in this scenario. In the RC scenario, spatial conflicts are likely to arise. Hence the suggested adaptation option may not be future-proof.

To summarize: the problem-oriented approach refers to 'society-proofing' climate policies and climate proofing 'normal' policies. It assesses whether a given policy or strategy will be robust to different future conditions. The systems approach sketches possible future societies and what problems are likely to occur in such societies. Based on these identified problems it formulates new policies. In the next chapter we discuss two cases: the Safety first project took a problem-oriented approach whilst the LANDS project is an example of a systems approach.

6 Case studies

6.1 Introduction

Below we discuss two CcSP projects where socio-economic scenarios played important roles. In the Safety First project WLO scenarios were elaborated by stakeholder consultations in several workshops. An important theme was the elaboration of more extreme scenarios, taking uncertainties and discontinuities into account. The LANDS project is a land use model driven project that translated WLO and climate scenarios into land-use maps for several other projects. The two cases were chosen as examples of good practice. Additionally they show very different approaches for elaborating scenarios. Safety first is a more qualitative approach that is primarily intended for discussing options for future flood management. LANDS takes a quantitative approach showing land-use patterns on a 100 m grid scale. Its results can be used e.g. for identifying future spatial conflicts.

Safety first primarily takes a problem-oriented approach as discussed in Section 5.2. Nevertheless it also applied backcasting techniques at some stages. The LANDS project generated land use maps by applying a systems approach, i.e. the future land use was determined given two combinations of socio-economic and climate scenarios.

6.2 Safety first

The research project *Aandacht Voor Veiligheid* (Safety First, AVV) provided inputs for the Deltacommissie (2008) that advised the Dutch Government about flood protection in the coming century. It was funded by Climate changes Spatial Planning, Living with Water and the Ministry of Transport, Public Works and Water Management. Socio-economic (and climate) scenarios played a crucial role in this project. Below the steps taken in this project to set up the socio-economic scenarios are elaborated. See Aerts et al. (2008) for the project's final report.

The AVV team concluded that the WLO scenarios were likely to be very useful for their project. At the start of the project they organized a workshop (in conjunction with IC11) to what extent the WLO scenarios needed to be modified or extended among a group of water experts and stakeholders, such as representatives from the ministry water department, provinces, municipalities, water-related research institutes, universities and consultancy firms. The workshop was moderated by scenario experts from Pantopicon (Antwerp). Three WLO-project members from the three planning bureaus (CPB, MNP and RPB) introduced the WLO-scenarios to the workshop participants, provided clarifications during the discussions and reflected on the workshop outcomes. See Annex I for the workshop's agenda. The workshop participants set up three PMI (Pluses, Minuses, and Interesting issues) matrices about WLO. Main conclusions were that WLO provided a good basis for the scenarios to be used in AVV, but that they wanted to look further into the future (2100) and users wanted to consider more extreme variants of the scenarios (Van Drunen et al., 2007).

The AVV team decided to extend two of the four WLO scenarios, Global Economy and Regional Communities, until 2100, building on the LANDS project (see Section 6.3). It used the IPCC SRES and additional demographic scenarios for this time extension (Van der Hoeven et al., 2007). The team also organized a second workshop with stakeholders to seek for possible solutions for climate change related floods, with 2100 as a time horizon. Informed by the first workshop, the AVV project team aimed to adjust the WLO scenarios in two ways:

1. Establish more variation between the scenarios (i.e. more discontinuous scenario plots) by stretching the WLO scenarios in such a way that they fit better to the Dutch (institutional) water context;
2. Include non-linear events and developments (i.e. more discontinuous storylines).

Therefore, AVV organized four additional workshops. In two backcasting workshops (Van de Kerkhof et al., 2007) it was identified what activities are required to reach a climate proof Netherlands in 2100. The 'interdisciplinary' workshop developed discontinuous storylines by identifying and systematically evaluating the direct and indirect effects of extreme events (Van 't Klooster, 2007b). The participants used maps, clay, paper sheets, post-it memos and marker pens to visualize their insights (Figure 3 and Figure 4). The 'governance' workshop, attended by policymakers and researchers, started with two extreme future perspectives and subsequent water management options to prevent flooding. Key question that was addressed was how to identify the necessary policies, institutional changes, new roles for stakeholders etc. (Van 't Klooster et al, 2007).

Figure 3 Maps, graphs and post-it memos were used to help the workshop participants expressing their visions.

The workshops generated a long list of possible discontinuities (Aerts et al., 2008:50) and possible implications for water safety in The Netherlands. Based on the evaluation of these discontinuities, the AVV team included the policy option 'elevation' in its analysis. This option and three other policy options were evaluated in the extended Regional Communities and Global Economy WLO scenarios (Aerts et al., 2008:128-134).

AVV aimed to develop a 'discussion support system': the AVV-DOS. The prototype of the AVV-DOS is described in Aerts et al. (2008: Ch.10). 'Future awareness' among its users is increased by systematically evaluating water safety policy options against different combinations of climate and socio-economic scenarios. The proposed users' session involves five steps:

1. The Netherlands in the long term: a combination of socio-economic and climate scenarios;
2. The effects in the 'do nothing' option, shown in maps;
3. Solutions: the user selects possible sets of measures;
4. Robustness of solution: an effects table and maps show the robustness of the sets of measures;
5. Moments of investments: here it can be decided where turning points are to be expected, i.e. when it needs to decided to invest or not.

The AVV-DOS challenges the user to 'play' with the available information. Hence, he will develop some sensitivity for the key parameters in the system and their implication on the water safety in the Netherlands.

Figure 4 Determining future images with a map and coloured clay.

6.3 LANDS

The CcSP project LANDS (IC3) identified climate-driven spatial changes in land us and land development. It integrated changes in agriculture, industry, housing and nature sectors into balanced national visions and regional solutions. Therefore LANDS implemented the WLO and KNMI scenarios into the land-use allocation tool *Land Use Scanner* (Dutch: *Ruimtescanner*). Instead of combining all possible combinations of socio-economic and climate scenarios LANDS took the extreme socio-economic scenarios and climate scenarios ‘to describe the broadest range of possible futures’ (Riedijk et al., 2007: 23). Hence the project considered the Global Economy (GE) scenario and the Regional Communities (RC) from WLO and combined these socio-economic scenarios with the KNMI W and G climate scenarios, respectively. Riedijk et al. (2007) do not distinguish between the climate scenarios with and without circulation changes. The main products of the study are two land-use maps for 2015 and two for 2040.

The Land Use Scanner simulates future land use by integrating sector specific inputs from dedicated models. The investigated sectors (agriculture, recreation, residential, nature, commercial, water, infrastructure) compete for allocation within suitability and policy constraints. The LANDS team applied a detailed 100 m grid and distinguished 17 land-use types. The general scenario descriptions were translated to land use with several sector-specific models and additional assumptions. In LANDS, maximum claims were assigned to the agricultural land-use functions as the LANDS team expects agriculture to provide the extra space needed for the other, economically more powerful land-use functions. The Land Use Scanner applies *suitability maps* to specify the spatial preference for certain land types. E.g. agricultural suitability is based on soil type and water level, nature to the ecological main structure and residential areas are attracted to current residential areas, forests and water (Dekkers and Koomen, 2006).

The LANDS scenarios provided inputs for Safety First and several other CcSP projects, including the Hotspot projects Zuidplaspolder (A14) and Groningen (A18) and the Adaptive Capacity to Extreme events in the Rhine basin project (ACER-A7).

7 Future research and recommendations

7.1 Simplifying models

The original aim of the IC11 project was to make (existing) socio-economic scenarios more user-friendly and transparent by integrating models that underlie these scenarios. This turned out to be too ambitious: more resources and inputs of institutes that host the models indicated in Section 3.1 would be required to make serious steps towards formal integration. Hence IC11 adopted another approach to user-friendliness. However, the original idea still seems to be a promising way to move forward. We think that CPB (Netherlands Bureau for Economic Policy Analysis) and PBL (Netherlands Environmental Assessment Agency) would be the best institutes to elaborate this idea further, because they have the easiest access to the majority of the models and data. It would result in 'WLO-lite', a socio-economic scenarios generator.

7.2 A scenarios resource

Scenario studies are generally set up as projects with specific start and end dates. In many cases the scenario developers start doing all kinds of other things after they have finished their project. However it would be attractive if a small team of experts would be available to follow the developments in scenario studies and keep some of the scenario outcomes up-to-date. A practical example would be the maintenance of the climatescenarios.nl website. Such a team could also support researchers who apply socio-economic scenarios, e.g. in the KfC programme. Possibly the PBL would be a good institute to host such an experts team.

7.3 Feedbacks

We noticed that scenarios tend to disregard feedback mechanisms between the socio-economic and the climatic system (e.g. adaptation strategies), although there is a recognition that the scale of an impact will be dependent on the level of social response – vulnerability and adaptation are linked to each other (Berkhout and Van Drunen, 2007). The WLO scenarios also have no feedbacks included, such as the effects of congestion on economic growth and the recreational area size decrease on the demand for houses with gardens. For the CcSP and KfC programmes the climate system – socio-economic system feedbacks need to be explored in more detail. Questions to be addressed include: 'how does climate change affect (regional) economic parameters?', 'how does climate change affect people's lifestyles?', and 'to what extent are mitigation policies successful?'. Especially the latter question is sometimes difficult to address in socio-economic scenarios, because they tend to include only current policies and serious mitigation measures require innovative (international) policies. The introduction of all kinds of policies in scenarios would seriously complicate the interpretation of their outcomes. Hence this issue needs to be resolved in the KfC programme.

7.4 Discontinuities

The idea of discontinuity appears appealing to scenario specialists, but it seems that in the course of a foresight exercise, radical outlooks get increasingly disqualified as exotic, implausible or unrealistic. In the end, the discontinuous repertoire is often marginalised in the foresight practice (Berkhout and Van Drunen, 2007). Although several theoretical and practical problems arise if discontinuities are incorporated into scenarios (cf. Van Notten et al., 2005), in climate assessments these may be particularly relevant since climate change itself can cause such discontinuities. Therefore it is necessary to address these theoretical and practical problems in the KfC programme.

7.5 Visualizations

Visualizations of future societies are essential in scenarios communication. Maps, sketches, clay models, mind maps and graphs often support storylines and tables with numbers to provide insights in possible future societies. However maps are not as simple and straightforward as they seem. Janssen and Uran (2003) showed that most users prefer maps and graphs above tables and text for spatial decision support systems. However, users tend to be overconfident regarding their own ability to use maps: even the users with a high preference for maps were not able to draw the right conclusion from a set of maps that was shown to them. In addition, the way maps actually look affects perceptions of e.g. (outcomes of) policy plans. Nevertheless new GIS technologies such as the *Touchtable* are an important tool for visualization of spatial impacts in socio-economic scenarios.

7.6 Incentives

We mentioned earlier (Berkhout and Van Drunen, 2007) that studies which seek to assess future impacts of and adaptation to climate change need to look at a range of different future socio-economic conditions. Imposing future climate on only one (current or future) set of economic, technological and social conditions does not give a broad-enough representation of possible outcomes. This approach downplays rather than explores the various sources of uncertainty, and compresses rather than reveals different interpretations of reality. Based on our inventory of user needs (Eeltink and Van Drunen, 2008) we have the impression that in many CcSP projects socio-economic scenarios were not seriously considered, whereas climate scenarios were. Therefore we recommend the KfC board to include incentives for applying socio-economic scenarios in projects that deal with adaptation planning. As a minimum (adaptation) policy recommendation must be discussed against the WLO Regional Communities and Global Economy scenarios.

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